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(54) Projection Exposure System

(57) Summary
Purpose

To control, with high velocity, a relative position shift between a mask stage and a board stage during scanning exposure.

Structure

In a step-and-scan method of exposure system, using the position information provided from reticle stage interferometer 16 and the position information from wafer stage interferometer 9, it computes a relative position shift as compared with original positions of reticle 14 and wafer 5 during scanning. Based on the computation results, it tilts clear plates 20 and 21 in order to shift a projected image on wafer 5 from reticle 14 so that a relative position shift is compensated during scanning exposure.

Claims

[Claim 1]

In a system, that is equipped with a mask stage, with a mask on which the original pattern is formed, which is movable at least in the first direction in alignment with the surface of the aforementioned original pattern, a projection optical unit which projects the aforementioned original pattern or part of the original pattern in a specified magnification, a plate stage which is movable at least in the aforementioned first direction, maintaining the position of photoresist plate on the image formation surface of said projection optical unit, and a drive method to make the aforementioned mask stage and the aforementioned plate stage travel with a velocity ratio in accordance with the aforementioned magnification, scans and exposes a projection image of the aforementioned pattern on the aforementioned photoresist plate, a projection exposure system is characterized by having clear plates, that are placed between the aforementioned mask stage and the aforementioned plate stage, and that are tiltable in order to displace the aforementioned projection image in the aforementioned first direction or the second direction that is orthogonal to said first direction, a position shift detection method which outputs a detection signal in accordance with a position shift amount when compared the aforementioned mask stage and the aforementioned plate stage in relation to the specified relative positions in the aforementioned first direction or second direction and a control method which tilts the aforementioned clear plates in the aforementioned first direction or the aforementioned second direction in accordance with said detection signal.

[Claim 2]

The aforementioned position shift detection method is a projection exposure system described in claim 1 that is characterized in that a detection signal is output in response to changes in the velocity ratio between the aforementioned mask stage and the aforementioned plate stage.

[Claim 3]

The aforementioned position shift detection method is a projection exposure system described in claim 1 that is characterized in that a detection signal is output in accordance with the aforementioned position shift amount regarding the first direction and a detection signal in accordance with the aforementioned position shift amount regarding the second direction, and that the aforementioned clear plates consist of the first clear plate that is tiltable in order to displace the aforementioned projection image in the aforementioned first direction and the second clear plate that is tiltable to displace the aforementioned projection image in the aforementioned second direction, and that the aforementioned first clear plate and the aforementioned second clear plate are placed side by side in the optical axis direction of the aforementioned projection optical unit.

Detailed Explanation of the Invention

0001

[Industrial Field of Application]

The present invention relates to a scanning type projection exposure system that is used in manufacturing semiconductor devices or liquid-crystal display devices, etc. and particularly relates to a positioning method during scanning exposure.

0002

[Prior Art]

Up to now, there are roughly two exposure methods in this type of projection exposure system. The one method is to expose photoresist plates such as wafer and plate by a step-and-repeat method via a projection optical unit that has a exposure field comprehending the entire original pattern, and the other method is a scanning method in which the original pattern and the photoresist plate are placed facing each other, having a projection optical unit in the middle, and the original pattern and the photoresist are relatively scanned and exposed under a circular slit illumination light. A stepper that uses the former step-and-repeat method is a leading system in the recent lithography process. This is because it has achieved higher resolution, higher overlay accuracy, higher throughput, etc. respectively as compared with an aligner that uses the latter scanning exposure method. It is considered that the stepper will continue to be a leading system for some time in the future.

0003

In this step-and-repeat method, a position shift correction of the original pattern that is installed on the mask stage and the photoresist plate that is installed on the plate stage prior to exposure is performed using an alignment system that is mounted inside the exposure system. Then, as a relative positioning of the original pattern and the photoresist plate is completed by the alignment unit, an illumination light from an illumination unit for exposure is irradiated on the original pattern for a specified time, and the photoresist plate is exposed, while maintaining the original pattern and photoresist plate not to cause any position shift during that time.

0004

Incidentally, a new method that achieves a higher resolution in the projection scanning exposure method is recently suggested as a step-and-scan method in pages 424 to 433, Optical/Laser Microlithography II of SPIE Vol. 1088 (1989). The step-and-scan method uses a scan method that, while scanning the original pattern in the one-dimensional direction, scans a wafer in the one-dimensional direction with a synchronized velocity, together with a step method that makes a wafer stepping in an orthogonal to the scanning exposure direction.

0005

Figure 4 is a diagram explaining a concept of a step-and-scan method. Here, scanning exposure is performed on rows in a shot range (one chip or multiple chips) in the x direction on photoresist plate W by means of circular slit illumination light RIL, making photoresist plate (wafer) W stepping in the Y direction. In the same figure, dotted arrows show an exposure route of a step-and-scan (hereinafter referred to as S&S), and a S&S exposure is first performed in the order of SA_1, SA_2, ..., SA_6 of the shot range and then in the order of SA_7, SA_8, ..., SA_{12} of the shot range that are arranged at the

center and in the Y direction of wafer W in the same manner. In the aligner using a S&S method that is disclosed in the above literature, an image of the reticle pattern illuminated by circular slit illumination light RIL is formed on wafer W through a ¼ reduction projection optical unit; therefore, a scanning velocity in the X direction of the reticle stage is precisely controlled as four times faster as compared with a scanning velocity in the X direction of the wafer stage. Also a reason why circular slit illumination light RIL is used is to make the most of an advantage in that various aberrations become almost zero in a narrow range (an annular shape) of an image height that is a fixed distance away from the optical axis, by using a reduction unit that combines a refraction device and a reflection device as a projection optical unit. An example of such reflection reduction projection unit is disclosed, for example, in USP. 4,747,678.

0006

[Problems That the Invention is to Solve]

In a-step-and-repeat method exposure system, a mask stage and a plate stage only needs to remain stationary keeping the specified position relationship during exposure; therefore, a structure to control factors (stage settling accuracy, etc.) causing the position relationship out of order is easily realized. On the other hand, in a-step-and-scan method, a mask stage and a plate stage move relatively in accordance with the specified velocity ratio during exposure; therefore, a relative position shift occurs between the mask stage (original pattern) and the plate stage (photoresist plate) due to a velocity irregularity or other factors during this movement.

0007

In this-step-and-scan method, as a means of compensating a relative position shift that occurs during exposure, it is considered that placing a fine mechanism on a mask stage or plate stage for scanning and driving the fine mechanism in accordance with an amount of relative position shift of the mask stage and plate stage, so that compensation is constantly performed during exposure. However, with this means, it is difficult to reduce the weight of the fine mechanism when its structure is concerned and it does not necessarily have good responses. Thus, the present invention aims to provide a system with higher responses of compensating a position shift (velocity irregularity) that occurs during exposure.

0008

[Means Used to Solve the Problems]

With the present invention, in a-step-and-scan method projection exposure system, clear plates, 20 and 21, that are tiltable in the first direction that is the same direction with the scanning direction of the mask stage or that are tiltable in the second direction that is orthogonal to the first direction, are installed in an image formation optical path between the mask and the photoresist plate, and furthermore control unit 23 that detects an amount of relative position shift during scanning exposure, based on the position information output from mask stage position detection unit 16 (reticle stage interferometer) and plate stage position detection system 9 (wafer stage interferometer), or that detects changes in the velocity ratio, based on velocity signals output from reticle

stage drive unit 17 and wafer stage drive unit 8, and clear plate drive unit 22 that makes the clear plates tilt in accordance with the amount of position shift are installed.

0009

Effects

The present invention utilizes a function to shift an original pattern image to be projected on a photoresist plate in a small amount within a projection field, by tilting the clear plates installed between a mask (reticle) on which the original pattern is formed and a photoresist plate. Therefore, compared with a means to compensate positions during scanning exposure of the original pattern by placing a fine mechanism on the mask stage, the present invention can achieve a higher response because it utilizes generally light-weight clear plates.

0010

Also, if clear plates are installed in the-step-and-repeat method, the clear plates that cover an entire exposure range (projection field) are required; however, in the-step-and-scan method, only a exposure slit range needs to be covered, that makes the area of clear plates smaller and furthermore contributes to a higher response.

0011

[Working Examples]

A system configuration of a-step-and-scan method, which the present invention explains, is basically identical with a system disclosed in Japanese Patent Publication No. 4-196513; therefore, the basic area of the system is briefly explained. Figure 1 shows a configuration of the projection exposure system by the working example of the present invention, and in which an illumination light emitted from a light source such as an Hg lamp, Excimer laser, etc. is reshaped in a rectangular slit illumination field by an image formation type illumination field stop prior to being projected on reticle 14. The pattern that exists within the illumination range on reticle 14 is projected and exposed on wafer 5 via projection lens 10. Here, a scanning exposure is achieved by making reticle 14 to scan from left to right within a space shown in figure with constant velocity V and by simultaneously making wafer 5 to scan from right to left within the space with constant velocity V/M (1/M is a projection lens reduction ratio).

0012

Explained is a driving structure of reticle 14 and wafer 5: Mounted on reticle support pedestal 11, for scanning exposure, is reticle Y-axis stage 12 which is possible to drive in the Y-axis direction (a right and left direction in reference to the space) and mounted on it is reticle fine stage 13 which is possible to perform a fine position control with a high accuracy in the X, Y and di r ections, and reticle 14 is held on reticle fine stage 13. On reticle fine stage 13, movable mirror 15 is arranged and the two-dimensional coordinates position is always monitored by reticle stage interferometer 16 mounted on reticle support pedestal 11. Meanwhile, mounted on wafer stage support pedestal 1, for scanning exposure, is Y-axis stage 2 which is possible to drive in the Y-axis direction and mounted on it is X-axis stage 3 which is possible to drive in the X-axis direction, and installed furthermore on it is Z-ax i s stage 4 which performs not only a parallel

translation in the Z direction that is vertical to the XY surface but also a fine rotation within the XY surface. Wafer 5 is held above it by vacuuming. On Z-axis s t age 4, movable mirror 7 is installed and wafer stage drive unit 8 which drives wafer 5 at any position or velocity in accordance with the two-dimensional coordinates position of movable mirror 7 monitored by wafer stage interferometer 9 is also installed. Also as mentioned later, there is fiducial mark plate 6 (hereinafter referred to as FM 6) on Z-axis stage 4 in order to cope with a wafer coordinates system determined by wafer stage interferometer 9 and a reticle coordinates system determined by reticle stage interferometer 16. To observe marks on FM 6 and marks on reticle 14, reticle alignment unit 18 is installed along with deflection mirror 19.

0013

Furthermore, wafer alignment unit 24 to observe marks on wafer 5 is installed in close vicinity to projection lens 10. Alignment of reticle 14 and wafer 5 is conducted, by obtaining a relative position relationship between a projection position at the center of reticle 14 and the detection center of wafer alignment unit 24 through FM 6 and by positioning alignment marks (position detection) on wafer 5 via wafer alignment unit 24 just before exposure.

0014

Now, clear plate 21, installed in the projection optical path between reticle 14 and projection lens 10, has a structure to be able to tilt in the direction orthogonal to the scanning direction and clear plate 20 has a structure to be able to tilt in the scanning direction. And clear plate drive unit 22 drives clear plates 20 and 21 from the origin in accordance with a tilt amount given by a command from control unit 23.

0015

Control unit 23 has, at the time of reticle alignment, functions to provide commands to reticle stage drive unit 17 regarding the starting and ending positions of scanning and how to cope with a wafer coordinates system based on alignment signals indicating a position relationship of the reticle alignment mark and FM6 received from reticle alignment unit 18 and position information from wafer stage interferometer 9. Also, control unit 23 has, at the time of exposure, functions not only to provide wafer stage drive unit 8 and reticle stage drive 17 with commands to operate scanning at a specified velocity ratio, but also to monitor a position change in the two-dimensional coordinates of the wafer coordinates system and the reticle coordinates system during exposure by wafer stage interferometer 9 and reticle stage interferometer 16 and to computes a relative position shift amount as compared to the original position relationship at the time of scanning exposure of reticle 14 and wafer 5, and to instruct a tilt amount for clear plate 20 or 21 based on the computation result.

0016

Figure 2 (1) shows an arrangement example of clear plate 27 in relation to projection lens field 26 if this type of clear plate is used in the-step-and-repeat method, and this requires a clear plate that covers the entire effective exposure range on a reticle; on the other hand, as figure 2 (2) shows, in the case of a step-and-scan method, clear

plates 20 and 21 can be just large enough to cover the rectangular slit illumination range that illuminates on a reticle. Thus, the size and weight of clear plates can be reduced, improving control capability to make a higher velocity control possible during exposure.

0017

Figure 3 shows positioning errors, which occur during a step-and-scan exposure, that are grouped into three classes. Figure 3 (1) is an offset in the X and Y directions of the entire shots and that is caused by a error occurred in the specified relative position relationship between a reticle and a wafer at the time of alignment This figure shows a relation of actually exposed shot range B to ideal shot range A. Next, figure 3 (2) shows the case in which a reticle and a wafer relatively fluctuate in the longtitudinal direction of slit illumination range 28, and fluctuation appears in actually exposed shot range B as compared with ideal shot range C. In this figure 3 (2), as a relative scanning of a reticle and a wafer proceeds in the amount of width (L) in the scanning direction of slit illumination range 28, fluctuation in the direction orthogonal to the scanning direction exceeds the allowable value. Furthermore, figures 3 (3) to (5) show fluctuation within width L of slit illumination range 28. Figure 3 (4) shows how a slit moves the distance equal to slit width L from position F to position G over shot range E. During this traveling, if fluctuation occurs in the X direction that is vertical to the scanning direction as shown in a graph of figure 3 (3), an image (an image obtained as computation to a resist image on a wafer) projected at point H within ideal shot range E shows a deterioration of intensity distribution as shown by pattern image J against ideal pattern image I as shown in figure 3 (5). This phenomenon applies to fluctuation occurred in the scanning direction as well.

0018

As these errors can be read from the difference between each position measurement value of wafer stage interferometer 9 and reticle stage interferometer 16, the difference in measurement values of wafer stage interferometer 9 and reticle stage interferometer 19 during exposure is computed by control unit 23, and if the difference exceeds the allowable value, each error described above can be eliminated by tilting clear plates 20 and 21 with a high velocity using clear plate drive unit 22.

0019

Here, an error compensation method concerning the scanning direction when clear plate 20 is used is explained in concrete terms. For example, if a 1/5 reduction projection optical unit is used for projection lens 10, and if a read resolution of wafer stage interferometer 9 is 0.01m, and a read resolution of reticle stage interferometer 16 is 0.02 m, the pulse ratio P_w / P_r of pulse signal P_w output from wafer stage interferometer 9 and pulse signal P_r output from reticle stage interferometer 16 per time during exposure becomes 5/2. Control unit 23 constantly monitors this ratio, for example, an every few millisecond and if the ratio exceeds the previously set allowable value, it sends a drive signal in accordance with an amount shifted to clear plate drive unit 22 to drive clear plate 20. Since the operation process mentioned above requires a high velocity process, a digital arithmetic circuit (hardware) that consists of a divider and a comparator, etc, rather than a software-based process is desirable for control.

0020

With the above working example, a position detection is performed by wafer stage interferometer 9 and reticle stage interferometer 16, and a relative position shift from the original position relationship between the wafer and the reticle during scanning is detected and it is controlled to compensate the shift amount. Apart from this method, for position shift control in the scanning direction, a circuit (velocity change detection circuit) which detects the velocity signal ratio obtained from each velocity sensor installed on reticle stage drive unit 17 and wafer stage drive unit 8 is installed, and if the ratio deviates from the specified value, it is possible to perform a position shift control by tilting clear plate 20.

0021

Furthermore, if position compensation by clear plates of the present invention is combined with reticle fine stage 13 that is placed on reticle Y-axis stage 12, fluctuation of larger amplitude in low frequency is compensated by reticle fine stage 13 and fluctuation of smaller amplitude in high frequency is compensated by clear plates 20 and 21, a rotation amount of clear plates 20 and 21 can be made smaller, and a configuration using piezo elements can be employed for high frequency, so that a higher accuracy and higher velocity can be expected. Also, clear plates 20 and 21 are not necessary to be placed between reticle 14 and projection lens 10, and they may be placed between wafer 5 and projection lens 10.

0022

By tilting lens components of projection optical unit 10, instead of these clear plates 20 and 21, position shift control is also possible.

0023

[Merits of the Invention]

As explained above, with the present invention, in a-step-and-scan exposure system, by tilting clear plates placed between a mask stage and a plate stage, a relative position shift of the mask and exposure plate during scanning exposure or velocity irregularity can be compensated with high responses. Consequently, not only shifting an entire shot range that needs to be exposed, but also reduction of shot deformation or image deterioration becomes possible.

Brief Explanation of the Drawings

Figure 1 is a diagram showing the entire structure of the projection exposure system pertaining to a working example of the present invention.

Figure 2 is a diagram showing comparison of the size of clear plates used in a step-and-repeat exposure method and a step-and-scan exposure method.

Figure 3 is an explanatory diagram showing various errors that occur in a step-and-scan exposure method.

Figure 4 is an explanatory diagram showing a concept of the existing step-and-scan exposure method.

Explanation of Code Numbers

1	Wafer stage support pedestal
2	Y-axis stage
3	X-axis stage
4	Z -axis stage
5	Wafer
6	Fiducial mark plate
7	Movable mirror
8	Wafer stage drive unit
9	Wafer stage interferometer
10	Projection lens
11	Reticle support pedestal
12	Reticle Y-axis stage
13	Reticle fine stage
14	Reticle
15	Movable mirror
16	Reticle stage interferometer
17	Reticle stage drive unit
20, 21	Clear plates
22	Clear plate drive unit
23	Control unit

Figures:

Figure 1

Figure 2

Figure 3 (1), (2), (3), (4) and (5)

Figure 4